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To my dog
and my cat.

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CHAPTER 11

Human factors in autonomous driving systems: A user perspective

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Automated driving systems (ADS) are the systems which work with little or no human assistance. Ride safety of user/ customer is an essential aspect of autonomous vehicles. It is the human factor that affects the usage of autonomous vehicles. This chapter aims to narrate the types of autonomous systems designs and human facets related to them. Interaction of users with autonomous vehicles has multiple dimensions, namely - robotics, psychology, policy and economics. Artificial intelligence systems can assist in addressing challenges posed by each of these dimensions. Amongst these components, the psychology component of user interaction is an important factor for ADS development and acceptance. Technological advancements, associated with assistance to drivers, reduce distractions and improve safety but trust in these technologies for augmenting driver capabilities is a must. Enhancement of drivers' self-awareness and potential distraction awareness associated with technology can be achieved through cognitive engineering principles. Successful deployment of ADS can help to improve mental health and social well-being in the local environment. It requires an effective collaboration between manufacturers and governments (local and central), that can provide the best suitable automated diving system. This chapter discusses these aspects in detail and in the process, underlines the criticality of the human-centric nature of ADS during its usage.

11.1 INTRODUCTION

ADS are being developed since the 1920s. The technology has seen its evolution through transmission of guiding signals, image processing algorithms like Cart's Vision algorithm, Blocks World planning method, bifocal camera systems, EMSVision autonomy system. With the overall development of technological know-how specifically related to computer technology, this development process accelerated. However, in addition to the technological dimension, the ADS also has an equally crucial human dimension. The human dimension encompasses both the elements of the automated road transport system – an ADS user as well as the non-ADS users of the road. In this chapter, we discuss the human factors in the ADS from a users' perspective. The broad question being investigated here is how do users take on the ADS. Specifically, we examine how do the psychology, economic, environmental and social factors of the user environment affect the use of ADS?

Recently, Chan (2017) [3] discussed what benefits ADS could incur under ideal situations. These include increased comfort and safety, reduced travel-related stress, efficient utilisation of the resources such as vehicles and fuel, reduced requirement of the ownership and lastly, more inclusive driving experience for incapacitated users. However, currently owing to limited penetration of ADS, lack of infrastructure and nascent stage of technological development, these benefits cannot be realised to their fullest potential. In this regard, Kyriakidis *et al* (2019) [10] interviewed several researchers in the field of ADS and brought out critical research areas for ADS and long term recommendations for successful deployment of the ADS. However, they did not explicitly analyse the human factors that are related to ADS from the user perspective. The understanding of the user perspective is critical for the ADS development process. Here, we address this particular aspect and investigate, from a user perspective, various dimensions of the ADS related to human factors.

In the next section, we discuss how the users perceive the different levels of automation. Then, we look into the design principles of ADS from a user perspective in the third section. These sections probe different aspects of ADS from a user perspective with a holistic outlook. The penultimate section focusses on the psycho-social factors related to the user and the ADS. The chapter culminates with a summary and concluding remarks.

11.2 LEVELS OF AUTOMATION

Development of the ADS can be characterised in terms of levels of automation achieved [8]. Formerly known as Society of Automotive Engineers, now SAE International has described ADS in six levels, from 0 to 5, where level 0 represents the no automation and 5 represents the full driving automation. These are shown in Figure 11.1 (A). This figure also shows the user perception of different ADS aspects in light of levels of automation. In this section, we discuss, how a user perceives these levels of automation.

With an increase in the level of automation, the safety features are improved; as a result, the users' perceive them as safer. Simultaneously, elements providing comfort are also included in the ADS in an accelerated fashion. These developments require more investment for infrastructure build-up. Hence, the cost for a private user continues to increase with the level of ADS until the penetration of such technology becomes all-pervasive. However, on the other hand, the cost of sharing user is expected to reduce as the level of automation increases owing to the optimised rerouting and reduced travel time.

From the users' perspective, the system complexity increases significantly with the level of automation. As a result, their understanding of how the vehicle or its components function remains at a comparatively rudimentary level. This factor, coupled with resistance to adopting newer technologies, creates a lack of trust in users towards ADS. This trust deficit also encompasses data privacy and security concerns. Subsequently, users' acceptance of ADS and their willingness to pay for ADS are adversely affected. The psycho-social aspects are discussed in more details in Section.

Proposed metric for ADS hierarchy: The levels of ADS as discussed earlier only address the production side, that is, the vehicle manufacturers and service providers. A need to measure the level of automation regarding ADS of a society/country/province/region is felt. Here, taking inspiration from the International Federation of Robotics, we propose a metric for determining the level of ADS in a society as the number of highest ADS level commercial vehicles per million ADS commercial vehicles at the second highest level. This metric reflects the level of advancement of that particular society in the field of ADS. It assumes that when the society advances to n^{th} level, the infrastructure and systems to adequately support $n-1^{th}$ level is in place. This metric can easily be used to compare any two societies with respect to ADS development. The levels can be indicated in the format: $LX-Y$, where X represents the highest level and Y represents the number of level X vehicles per million of X-1 vehicles. For example, number of cars with level 1 ADS features in India in 2015 was about 276 thousand [2], and level 0 vehicles was about 28,860 thousand [1]. Hence, the place of India according to the proposed ADS hierarchy metric would be L1-9680.

11.3 DESIGN PRINCIPLES OF ADS FROM THE USER PERSPECTIVE

Fridman (2018) [6] discussed the design principles of shared autonomy ADS which typically lies between level 3 and 4 of the automation. In this section, we will first briefly describe the design principles and then discuss each of them from the point of the user.

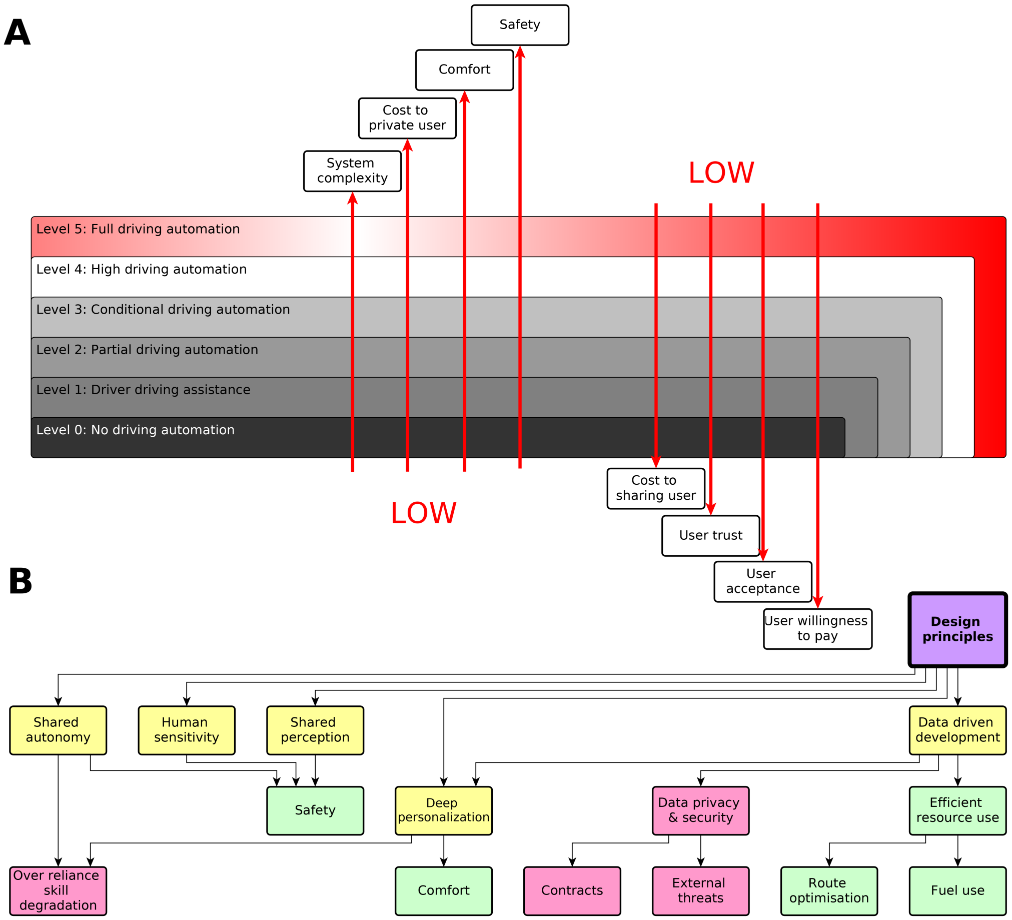

Figure 11.1 **(A)** depicts the levels of automation from a user perspective. Levels of automation with keyword description is shown on the left side. The arrows represent the increase, in the direction of arrow, in the particular aspect being represented. **(B)** shows the design principles of ADS: Benefits and the concerns associated with the design principles are depicted here. Arrows indicate the influence, green and red coloured boxes show the benefits and concerns respectively.

11.3.1 The design principles

According to the first design principle, the team of human and machine should be considered cohesively. The situation awareness can be very well anticipated by human and hence, can contribute to better handling of perception control problems. Perception is the point that allows a driver to control the actions and the consequences of them. It recommends prioritisation of the development of human-machine interaction over the perception control.

The evolution of ADS takes place through the learning process, which depends upon the data obtained from various sensory systems. The second principle addresses this evolution process and suggests to exploit the modern machine learning techniques to develop each of the systems such as mapping, localisation, scene perception, teleoperation, external human-machine interface and so on. The overall goal of this evolution process is to move from a supervised learning system to a more independent semi-supervised and unsupervised system.

The next three principles focus on how the systems should be developed so that they can complement the humans in the process of driving. These are critical from a safety point of view. The system should be able to gauge the state and capabilities of humans. Moreover, ADS should be able to perceive the environment as a human and supplement this perception with additional information to facilitate the human to make the best choice. Such a process cannot be completed unless the human is aware of the capabilities and limitations of the ADS. The fifth principle builds upon the four other principles and warrants the system to adapt itself to the human using the sensory and behavioural information and evolve to provide a deeply personal experience to the human.

The sixth principle branches off from the shared perception concept and insists on sharing how the system sees the world and its limitations so that a synergistic relationship can be built between the two. The last principle recommends the ADS development process to optimise both the safety and the enjoyment at the system level.

11.3.2 The user perspective

Figure 11.1 (B) summarises various design principles and sheds light on each of them from the users' perspective. Let us look at the benefits from a user perspective. The first and the foremost, owing to data-driven development and connected systems the ADS facilitates efficient use of available resources such as optimal routes leading to shorter transit times, and less congestion means lower fuel wastage. Hence, for a user, ADS can serve two purposes. First, it reduced transit times means the user has more time available at her disposal. This a tangible economic benefit. However, this benefit also has social value. Availability of spare time can encourage the user to enrich the lives of people around her and also of herself. Secondly, the optimal use of shared-access infrastructure (roads - highways, flyovers, bridges) can prolong their life; hence, need maintenance. As a result, under ideal conditions, the economic burden on the user, associated with building and maintenance of infrastructure, in the form of taxes is expected to be reduced. Moreover, on a national level, such savings can be invested in other fields such as health, education, economic support programs for less affluent people and so on. Thus, creating social value. The psycho-social aspects are discussed in detail in Section 11.4. However, these benefits to the user are not limited to economic and social dimensions, lower congestion and shorter transit times lead to efficient use of the fuel. Hence, emissions are expected to reduce. This environmental benefit, though, has a global effect, but, less pollution is expected to have positive effects on the health of the users.

Another critical aspect of the ADS is shared autonomy, where the human and machine work together. The system attempts to understand how the user perceives the surrounding. It also shares its perception of the surrounding with the user, thus, providing her with a more holistic picture. As a result, users' safety is expected to increase. Such benefit depends on the synergy between the user and the system, that is, how well the user can understand the capabilities and limitations of the system and vice versa. This understanding of the user by the system leads to its deep personalisation, hence, increasing the comfort level of the user during the travel. The comfort may come from the confidence in the system to carry out allocated tasks or from the optimised rerouting based on personal choices of the user leading to reduces stress levels.

Apart from these positive influences on the users, certain concerns have been echoed since the genesis of ADS. One of the essential aspects of ADS development is learning and evolution based on the data acquired from various systems. Such data-driven development provides the user with an opportunity to achieve more efficient use of resources. At the same time, the users' concern regarding privacy and data security cannot be neglected. Several studies have brought this issue in light [5, 7, 12]. Eckhoff and Sommer (2014) [5] discussed the vulnerability of systems sharing data continuously and possible ways of circumventing these issues. However, one of the primary concern regarding data privacy, as brought out by them, was Automated surveillance. Any vehicle, embedded ADS, would share its information such as location, and velocity with the service providers on regular intervals. Thus, automatic ticketing for overspeeding or entering in the wrong direction could be considered as one of the benign forms of automated surveillance.

Hacker (2017) [7] argues that the contracts related to data are generally skewed in favor of the entities exploiting such data. Further, the regulatory framework should be capable to respond to and rein such practices. However, according to Hacker, the policy of the EU falls short on this front. In case of India, currently, the policy architecture has not been altered to allow the use of ADS [9]. More recently, Ren *et al* (2020) [12] reviewed the security threats to the ADS and suggested directions for future research. They classified the threats to the ADS and eventually to the user in three types, one corresponding to sensors and others related to the systems and protocols of the vehicles. These were not limited to the data privacy or security aspects, rather about possible vulnerabilities of ADS against a malevolent party. Hence, from a users' perspective, data privacy and security concerns are two-fold: the contractual relationship with the ADS service provider and the external threats.

Another vital concern is over-reliance of the user on the ADS and the subsequent skill degradation. This is a direct offshoot of the deep personalisation and shared autonomy. These two factors create a sense of complacence in the user. Continuous use of ADS might dull the users' skills and effectively increase the response time.

11.4 PSYCHO-SOCIAL ASPECTS OF ADS

The psycho-social factors related to ADS were discussed briefly in Section 11.2 and 11.3. The social aspect involves people and ultimately calls for the psychological involvement of the people. Reed (2016) [11] tried to narrate the psychological aspect and decision making functions. They considered autonomous vehicles as vehicles that could perform a subset of the desired driving task. They identified clumsy automation as the reason for the increased mental workload. The operation of ADS should be considered the evident status of the system and should be intuitive. The decision-making function in ADS may lead to a reduction in driver's awareness of system status and dynamic features of the operating environment. The driver may not be actively engaged in evaluating the information sources leading to decisions if the similar types of decisions are taken and executed due to the repeated use of reference material. The decision making task during the journey requires the performance of cognitively and visually demanding tasks due to the variability in the environmental conditions, traffic status and encountered pedestrians. Skill degradation of the driver can be predicted due to increased responsibility for the safe control of the vehicle. Shariff *et al* (2017) [14] also highlighted the psychological challenges and discussed modalities of tackling them. Accordingly, in order to overcome such challenges, the strategy chosen could unintended consequences. A strategy could either lead to public outrage if it is self-protective or may scare consumers if it is utilitarian. In both cases, it is tough to manage autonomous ethics. Autonomy ethics can be followed morally or can be prioritized as the lives of passengers' lives. The opaque process of decision making in ADS may result in diminishing trust.

A case study of Australian traffic and related people has presented their finding in 'Social Impacts of Automation in Transport' submitted to the House of Representatives Standing Committee on Industry, Innovation, Science and Resources [4]. The study elaborates the social acceptability of ADS under the umbrella of safety risks, mobility freedom and cybersecurity issues. Factors contributing towards the social acceptability of ADS include the safety of vehicle occupants, other road users and others near the road environment. The safety risks involved in hardware, software and the infrastructure poses a challenge. On the hardware front, such as failure of the critical supporting interface, interaction issues between human drivers and automated systems. On the software side, the change in operational parameters, testing decisions taken by the manufacturers' and cybersecurity risks. The infrastructure angle suggests the difficulties in traffic due to risk-taking on-road profiles. The literature suggests that ADS will get an acceptance if it provides mobility freedom to disabled people, older citizens and children. The social impact can be sensed if applied to public transportation. It may result in employment opportunities, education and training, government services, social activities and reduction in parking space requirements. If the automated vehicles do not generate increased travel on the road, then it will reduce congestion, sustainability and accessibility leading to increased livability. The biggest threat to ADS can be cyber-attacks due to vulnerabilities caused by extensive use of electronics, sensors and software components. The path of security management can be traced by shared responsibility of government, industry, that is public and private sectors together. The social acceptance of ADS can also be increased by providing legal certainty to consumers. The vehicles provided should be legally authorized, having appropriate insurance providing compensation for injuries and more importantly 'human drivers are not held responsible for actions in automated systems'. The automotive industry can utilize vast amounts of data generated from automated vehicles in increasing social well being of consumers. The data can be used to launch new services to consumers, making better infrastructure planning decisions, improvement in traffic management and asset maintenance. Various decisions related to investment can be enhanced due to the availability of travel information of passengers. Crash investigations can facilitate determination of fault. The road-related revenue at all levels of government can be seen as another aspect under the social impact. The safety improvements in ADS will increase the sale and ultimately, reduction in cost for the consumers. The cost reduction for consumers can also be achieved due to the efficient use of the current infrastructure of roadways. The revenue of the government for registration and licensing fees can be reduced if the private ownership is reduced. It may also result in lesser parking fees and traffic violation fees.

Sayer (2017) [13] has discussed aspects of the social dimension which need evaluation. He expected the time spent on autonomous vehicles to be more productive and less stressful than the usual manual vehicles. Also, issues such as loss of gesture due to the eye to eye contact and acknowledgment, implications for road funding, changes at the individual level and in the workplace relating to taxi, chauffeur and delivery jobs, changes in skills of driving, physical activity (like exercise) and social activity (like family time).

Coming to an end of the societal/social impact due to ADS a summary table —- can be generated from the transformations discussed in “Autonomous automobilities: The social impacts of driverless vehicles” by Bissell, David et al.(2020)[118].

Bibliography

[1] India motor vehicle registered, 2020. https://www.ceicdata.com/en/indicator/india/motor-vehicle-registered Accessed: 2020 July 28.

[2] Market volumes of sensors used in adaptive cruise control systems fitted to newly-assembled light vehicles in india from 2013 to 2033, 2020. https://www.statista.com/statistics/892807/adaptive-cruise-control-systems-sensors-light-vehicle-market-volume-india/ Accessed: 2020 July 28.

[3] Ching-Yao Chan. Advancements, prospects, and impacts of automated driving systems. *International journal of transportation science and technology*, 6(3):208–216, 2017.

[4] Department of Infrastructure and Regional Development, Australian Government. Social Impacts of Automation in Transport Submission to the House of Representatives Standing Committee on Industry, Innovation, Science and Resources . Technical report, February 2017.

[5] David Eckhoff and Christoph Sommer. Driving for big data? privacy concerns in vehicular networking. *IEEE Security & Privacy*, 12(1):77–79, 2014.

[6] Lex Fridman. Human-centered autonomous vehicle systems: Principles of effective shared autonomy. *arXiv preprint arXiv:1810.01835*, 2018.

[7] Philipp Hacker. Personal data, exploitative contracts, and algorithmic fairness: autonomous vehicles meet the internet of things. *International data privacy law*, 7(4):266–286, 2017.

[8] SAE international. Taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles, 2016. Accessed: 2020 June 28.

[9] VV Ravi Kumar and Parth M Doshi. India's policy architecture needs to be changed to allow autonomous vehicle revolution, 2020. Accessed: 2020 June 28.

[10] Miltos Kyriakidis, Joost CF de Winter, Neville Stanton, Thierry Bellet, Bart van Arem, Karel Brookhuis, Marieke H Martens, Klaus Bengler, Jan Andersson, Natasha Merat, et al. A human factors perspective on automated driving. *Theoretical Issues in Ergonomics Science*, 20(3):223–249, 2019.

[11] N Reed. Psychology and the automated vehicle. *J Psychol Psychother*, 6(273):2161–0487, 2016.

[12] Kui Ren, Qian Wang, Cong Wang, Zhan Qin, and Xiaodong Lin. The security of autonomous driving: Threats, defenses, and future directions. *Proceedings of the IEEE*, 108(2):357–372, 2019.

[13] Jim Sayer. Potential societal implications of autonomous vehicles, 2017. Accessed: 2020 June 28.

[14] Azim Shariff, Jean-Franffois Bonnefon, and Iyad Rahwan. Psychological roadblocks to the adoption of self-driving vehicles. *Nature Human Behaviour*, 1(10):694–696, 2017.